EDO Specialty Plastics (formerly Specialty Plastics, Inc.)

Composite Piping Systems to Improve Oil and Gas Production

From the mid-1980s until 1994, U.S. oil and gas exploration and production steadily declined, forcing a significant increase in U.S. imports of crude oil. For example, in 1994, the United States imported more than 50 percent of the nation's total demand, which was the highest level since 1990. To economically develop U.S. oil production in deep-water locations, the industry needed strong, lightweight materials to replace the heavy alloy traditionally used in oil platforms in seawater. If alloy pipe could be replaced with lightweight advanced composites, for example, benefits would include reduced weight on the platform deck, reduced cost of the piping, and reduced maintenance costs.

Specialty Plastics, Inc., makes composite pipes, fittings, and components for the petrochemical and marine industries. The company proposed to develop an improved method to join composite pipe segments and more efficient, less costly processes for manufacturing the pipe fittings. Because the technology was too risky for private investment, Specialty Plastics submitted a proposal to the Advanced Technology Program (ATP) in 1995 and was awarded cost-shared funding for a three-year project through ATP's focused program, Manufacturing Composite Structures. By the end of the project, Specialty Plastics had successfully developed an innovative, highly reliable joining method. The company had also developed a new manufacturing process for pipe fittings that increases production rates, reduces costs, and enhances component properties.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 95-11-0012 were collected during October - December 2002.

Composite Piping Attracts Industry Attention

In 1995, the deep-water offshore oil industry was looking for strong, lightweight materials to replace the heavy alloy piping used on oil platforms in seawater. By reducing the weight of the piping materials on the service deck of a tension leg platform (TLP), the buoyancy of the TLP would increase. This would reduce the amount of structural steel needed below water, thereby significantly reducing the cost of a TLP.

Although carbon steel and copper nickel alloy pipe had traditionally been used on offshore platforms, advanced composites were known to be stronger, more resistant to corrosion, and lighter than steel. For example, composite pipe with a 6-inch diameter weighs 4 pounds per foot, whereas copper nickel pipe with the same diameter weighs 24 pounds per foot. Advanced composites also cost less initially than steel piping and have a longer life cycle. At the time that Specialty Plastics applied for the ATP award, the estimated life cycle of composite piping in seawater was 20 years, compared to 7 years for steel piping.

There were, however, obstacles to using composite piping that were related primarily to the lack of test data to support the materials' long-term durability. Engineers who were used to alloy pipe were uncomfortable with composites. Also, composite pipe fittings were expensive and labor-intensive to manufacture, and the methods used to join composite-to-composite piping and composite-to-alloy piping were unreliable. In addition, oil companies and regulatory agencies, such as the U.S. Coast Guard and the Mineral Management Service, thought that it was too risky to use the largely unproven composite materials for vital services, such as transporting water for extinguishing fires on an oil rig.

Innovative Design Concepts and Manufacturing Processes Proposed

Advanced composite piping had previously been partially developed in a U.S. Navy surface ship program. However, extensive work had not been performed on reliable joining methods and low-cost fittings. When Specialty Plastics decided to continue research and development, composite pipes were still considered an emerging technology. Therefore, this area of research, with a return on investment of six to eight years, was considered too risky for private industry. Thus, Specialty Plastics submitted a proposal to ATP for funding.

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Specialty Plastics' primary goals were to develop new technologies for joining and fitting composite-to-composite and composite-to-alloy pipe segments and to develop more efficient, less costly processes for manufacturing the fittings. The company proposed to improve joint technology by developing an integral flange technology and a heat-activated coupling technology. The integral flange is a joining method in which filaments are wound directly onto a pipe or fitting, thereby eliminating the joint. Joining composite components in this way, without the use of mechanical joints, protects the mechanical integrity of the pipe and is considered highly reliable.

A heat-activated coupling system is a simple, cost-effective means of joining composite-to-composite and composite-to-alloy pipe segments. It involves placing the prepreg laminate, made of fiberglass reinforcements impregnated with thermoset resins, over the pipe ends to be joined and applying heat around the laminate so that the thermoset resins cure and the laminate shrinks to seal the joints.

One issue with heat-activated coupling is that the resins do not cure completely and uniformly. Also, because

An example of Speciality Plastics' joining and fitting of composite-to-composite and composite-to-alloy pipe segments.

metal is a better conductor and dissipates heat faster, the joining resins cure much more slowly on sections in contact with alloy pipe, resulting in leakage from these joints under normal loading conditions. To overcome these problems, Specialty Plastics planned to develop a computer-controlled heating device integrated with microsensors. The company also planned to design or identify joining resins that had desirable properties based on resin chemistry and curing behavior.

The company proposed to improve joint technology by developing an integral flange technology and a heat-activated coupling technology.

Specialty Plastics also sought to improve adhesive-bonded joints by enhancing the chemical bonding between the adhesive and the composites. Typically, adhesive and composite materials bond poorly due to the use of epoxy vinyl ester resins in fiberglass-reinforced structures and equipment. This has caused the failure of adhesive-bonded joints, generally at the interface between the adhesive and the composite surface. To overcome this problem, Specialty Plastics planned to chemically activate the joining surface so that the adhesive layer would be chemically bonded to it. The company also wanted to find a resin that had a chemical composition compatible with the joining surface.

Furthermore, Specialty Plastics planned to improve fitting manufacturing technology by developing intelligent-filament winding using optical sensors and by developing resin transfer molding (RTM) technology. In intelligent-filament winding, optical sensors are incorporated into a filament-winding machine, which is then programmed so the computer automatically turns the object to be wound and determines the winding process in real time. This improves productivity and assures the quality of the joint. It also substantially reduces the costs of small-volume production and increases production accuracy through in-process monitoring.

Corrosion of metal piping costs approximately $20 billion each year.

Finally, the company explored the use of RTM technology. RTM is a molding process used to produce composite parts in which continuous fibers are placed inside a mold in the form of a two-dimensional woven fabric and injected with resin. Specialty Plastics planned to improve this technology by also using three-dimensional preforms, which could be mass-produced and were strong enough to maintain their shape when injected with the resin. The resin system would be the same as that used for composite pipe.

Specialty Plastics Anticipates Broad-Based Benefits

Specialty Plastics estimated that the market would grow to more than $10 million within 5 years of funding and to more than $40 million within 10 years. Oil companies investing in TLPs could realize potential savings of $20 million in capital investment, as well as additional benefits such as lower maintenance and life cycle costs. These cost savings would reduce the overall operating cost of a TLP and would increase the return on investment to the operator.

An increase in the use of TLPs would lead to an increase in domestic production of oil and gas. This would decrease the nation's need to import large amounts of foreign oil, a U.S. expense of more than $1 billion per week in 1995 and half of the national trade deficit. Increased domestic production would also result in more jobs in the United States; for example, it has been estimated that a $30 million investment in oil and gas production can support 800 jobs in the oil and gas industry and even more in other areas of the economy.

Moreover, improved advanced composite piping systems would benefit industries where the corrosion of metal piping is a problem, such as the petrochemical industry, the commercial marine industry, and the pulp and paper industry. Corrosion of metal piping costs these industries approximately $20 billion each year.

Two New Processes Prove Successful

Specialty Plastics had to meet several requirements to achieve their goals of developing the integral flange, a heat-activated coupling system, enhanced chemical bonding between adhesives and composites, intelligent-filament winding, and RTM. These requirements and the company's related accomplishments are summarized below:

- Develop an optimal manufacturing procedure for integral flanges and computer programs to generate various winding patterns. Develop finite element modeling for integral flanges subjected to tension, bending, or both so that (1) material scraps are reduced, (2) the manual operation is eliminated, and (3) labor costs are reduced. ***Results:*** The company was able to reduce material scraps by 20 percent and labor costs by 20 percent as compared with the manual winding process used at the time.

- Develop a cost-effective process for manufacturing full-face flanges by using the integral flange technique. ***Results:*** The company reduced time and labor costs by 20 percent as compared with the currently used hand lay-up process.

- Complete the development and implementation of an optical system to assist in the design of winding patterns. ***Results:*** A Specialty Plastics achieved a reduction in the cost and a 15-percent reduction in the time required to generate patterns.

- Develop a mold for a reducer joint and an elbow mold, set up RTM experiments, and produce a reducer. ***Results:*** The company compared the final properties of the reducer and the elbow, such as fiberglass content, and found that they increased more than 10 percent by weight. The ability to hold internal pressure on a hydro test was compared with that of conventional reducers and elbows and found to have increased more than 10 percent.

Specialty Plastics achieved the majority of its goals; however, it was unable to improve the surface adhesion of composite materials. The company had sought to increase the operating pressure of composite piping to 400 psi through improved adhesion, but was able to increase it to only 225 psi, which limits the applications of the piping to about 75 percent of the seawater cooling systems on offshore TLPs.

Also, the company's work on RTM was only partially successful, resulting in a modified RTM technology. However, based on the research it performed during the ATP project, today the company is using a modified, state-of-the-art form of RTM technology in which an additional application of resin is applied to the fibers in a wet-layer process outside the mold. This method is not as efficient as the technology originally proposed, but it produces a stronger flange.

Composites Piping Market Increases

In 1998, Specialty Plastics began to market resin transfer molded flanges, reducers, and elbows and started to earn revenue. Their chief customers, Shell Deepwater, Exxon, and Texaco, were all operating in the Gulf of Mexico. The company also adopted process improvements for the RTM of the fiberglass pipe fittings it was already selling. In May 1998, the U.S. Coast Guard approved the use of composite piping in fire systems, which, according to Richard Lea, former President of Specialty Plastics, was a major victory. "It proved that composite materials could endure fire levels with medium-scale fire testing." Since then, the industry in the Gulf of Mexico has used composite piping for fire and seawater systems.

By 1999, Specialty Plastics had completed 38 major projects, and approximately 40 percent of its offshore oil and gas industry revenue came from the sale of composite parts. The company had approximately 50 customers. By the end of 2002, the company had completed 25 additional projects. Overseas companies in Australia, West Africa, and Malaysia are also beginning to purchase the technology.

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Specialty Plastics' success attracted attention from prospective buyers, and the company was purchased in December 1998 for $4.5 million by EDO Fiber Science. Specialty Plastics is now a subsidiary of EDO Specialty Plastics and generates annual revenues of approximately $15 million.

From 1995 to 1998, Specialty Plastics published numerous journal papers and presented papers at various conferences in the area of composite materials. In addition, three company employees received awards, including the "1997 Tibbetts Award for SBIR Model of Excellence," sponsored by the U.S. Small Business Administration.

Conclusion

With ATP's assistance, Specialty Plastics developed several innovative composite joining and fitting technologies for composite piping systems. The company also developed a new manufacturing process for pipe fittings that has resulted in higher production rates, lower costs, and improved component properties. The company did not, however, improve the surface adhesion of composite materials, and its work on resin transfer molding (RTM) technology was only partially successful, resulting in a modified, state-of-the-art form of RTM technology.

The reliable joining methods that Specialty Plastics developed during this ATP-funded project have led to an increased use of composite piping systems on offshore tension leg platforms (TLPs) by the oil industry with significant cost savings. Since 1995, the U.S. market for composite piping has grown from less than $2 million a year to approximately $20 million a year, with growth of approximately 20 to 30 percent a year. Composite parts from the new technology have also been sold overseas in Australia, West Africa, and Malaysia.

PROJECT HIGHLIGHTS
EDO Specialty Plastics (formerly Specialty Plastics, Inc.)

Project Title: Composite Piping Systems to Improve Oil and Gas Production (Innovative Development of Joining/Fitting Technology for Advanced Composite Piping Systems)

Project: To develop innovative composite joining and fitting technologies that will enable and stimulate the use of composites in offshore oil and gas production pipelines.

Duration: 9/20/1995-9/19/1998
ATP Number: 95-11-0012

Funding (in thousands):

ATP Final Cost	$1,809	70%
Participant Final Cost	773	30%
Total	$2,582	

Accomplishments: ATP funding enabled Specialty Plastics to successfully develop the following innovative composite joining and fitting technologies. These technologies have enabled and stimulated the use of composites in offshore oil and gas production pipelines.

- Integral flange technology
- Heat-activated coupling technology
- Improved fitting manufacturing technology through intelligent-filament winding using optical sensors

The company also developed a new manufacturing process for pipe fittings that increases production rates, reduces costs, and enhances component properties.

Specialty Plastics attempted to improve the surface adhesion of composite materials in order to increase the operating pressure of composite piping to 400 psi; however, it was not successful. The company did, however, achieve a pressure rating of 225 psi for the piping, which enables it to be used for approximately 75 percent of the seawater cooling systems on offshore tension leg platforms (TLPs).

The company also performed work on resin transfer molding (RTM), which was partially successful. The result was an advanced state-of-the-art form of RTM technology in which an additional application of resin is applied to the fibers in a wet-layer process outside the mold. This method is not as efficient as the technology originally proposed, but it produces a stronger flange.

In addition, from 1995 to 1998, Specialty Plastics published 14 journal papers, presented papers at 17 conferences, and presented findings at 8 conferences in the area of composite materials. The following are examples of the publications and presentations:

- Montestruc, A.N., M.A. Stubblefield, S.S. Pang, V.A. Cundy, and R.H. Lea. "Smoke and Toxicity Tests of Fiberglass-Resin Composite Pipe Samples." Composites, Part B: Engineering. Vol. 28B, p. 287-293. (1997).
- Montestruc, A.N., M.A. Stubblefield, S.S. Pang, V.A. Cundy, and R.H. Lea. "Fire Endurance Tests of Dual-Wall Fiberglass-Resin Composite Pipe." Composites, Part B: Engineering. Vol. 28B, p. 295-299. (1997).
- Pang, S.S., (Keynote Lecturer). "Advanced Composite Piping Systems in Offshore Oil & Gas Industry." Coauthored by S.S. Pang, R.H. Lea, C. Yang, and M.A. Stubblefield. Fourth International Conference on Composites Engineering. Hawaii. (July 6-12, 1997).
- Stubblefield, M.A., C. Yang, S.S. Pang, and R.H. Lea. "Development of Heat-Activated Joining Technology for Composite-To-Composite Pipe Using Prepreg Fabric." Polymer Engineering and Science. Vol. 38, No. 1, p. 143-149. (January 1998).
- Pang, S.S., R.H. Lea, and M.A. Stubblefield. "Advanced Composite Piping Systems in Offshore Oil & Gas Industry." AACP 1998 Science, Engineering and Technology Seminars (SETS). Houston, Texas. (May 23-24, 1998).
- Stubblefield, M.A., R.H. Lea, S.S. Pang, and Yi Zhao. "Innovative Development of Joining/Fitting Technology for Advanced Composite Piping Systems."

Three company employees received awards, including the "1997 Tibbetts Award for SBIR Model of Excellence," sponsored by the U.S. Small Business Administration.

Commercialization Status: In 1998, Specialty Plastics began to market resin transfer molded flanges, reducers, and elbows and started to earn revenue. Their chief customers included Shell Deepwater, Exxon, and Texaco. Specialty Plastics also adopted process improvements for RTM of the fiberglass pipe fittings they were already selling.

Outlook: The market for composite piping has grown significantly, from less than $2 million a year in 1995 to approximately $20 million a year in 2002. Moreover, future growth is estimated at approximately 20 to 30 percent per year. By the end of 2002, EDO Specialty Plastics completed 63 major projects in the Gulf of Mexico. The company is also beginning to sell products from this technology overseas, especially in Australia, West Africa, and Malaysia.

Composite Performance Score: * * *

Number of Employees: 65 employees at project start, 100 as of October 2002

Focused Program: Manufacturing Composite Structures, 1995

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